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The Start-up Venture Capital Innovation System
Comparison with industrially financed R&D projects system

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ABSTRACT
This paper concerns a study on the start-up venture capital (SVC) system, now becoming an important structure for generation of new technologies. SVC system may be considered an evolution of R&D projects system financed by industrial capitals. The study considers start-ups companies of technological nature characterized by carrying out not only R&D but also searching business models suitable for the developed technology. Venture capital (VC) owns the more radical aspect of the SVC system, looking for selling the developed technology or business, and refinancing new start-ups instead of exploiting the use of the technology as done by industrial capital financing R&D projects. The SVC system have the objective to reach an exit selling the developed technology or business and obtaining an adequate return of investment (ROI) for the VC. The SVC system operates in a financing and refinancing cycle that may reach an equilibrium when obtained ROI covers costs of both successful and abandoned start-ups and cost and rewards of VC. Should ROI be higher than the equilibrium value it might start an autocatalytic process generating a high number of technologies and ROI. The SVC cycle may be simulated mathematically showing that a selection strategy of financed start-ups based on high potential ROI and team validity gives in practice superior economic results in respect to a selection strategy based on the probability of a successful exit of the start-up. Comparison of SVC system and industrially financed R&D projects shows that the SVC system is superior in the development of radical technologies with suitable business models in respect to industrially financed R&D projects that are limited by pre-existent strategies in firms financing R&D.

KEYWORDS: Start-up, venture capital, R&D, business model.

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CONTENTS

1 INTRODUCTION

The Start-up Venture Capital (SVC) system represents another way to make technological innovations resulting from evolution of industrial R&D activities toward a distributed technological innovation system (Haour, 2004), accompanied by development of new business models in which it is called a regime of open innovation (Chesbrough, 2003). In fact, venture capital (VC) companies financing start-ups appeared already just after the 2nd World War in USA (Lerner 2000), but they found a great development only since the 70' especially in territories, such as the Silicon Valley, becoming an alternative to industrially financed R&D projects in developing technological innovations. Actually, looking to this system, it appears that its success is based on a radical new approach introduced by the VC in financing innovations, more than on activity of start-ups. Industrial capitals financing R&D projects have normally the objective to obtain a return of investment (ROI) exploiting the use of new technologies. The innovation of VC has overturned this objective by financing innovation, not by R&D projects but by start-ups, being disinterested in exploiting the new technologies, but selling the developed technologies and refinancing with this ROI new technology developments. In this way, when ROI are largely positive, it is formed an autocatalytic cycle of investments and reinvestments that, in technological fields with large innovative potential attracting capitals, as occurring in the Silicon Valley, leads to a great development. It is the objective of this study to describe in some detail the processes occurring in the SVC system and to compare this system with the industrially financed R&D projects system in developing technology innovation, and discussing limits and advantages of both systems.

The SVC system has gained little attention concerning its general technological aspects interfacing financing and technological risk management. In this work we limit our discussion to start-ups having as objective technological innovations, and they are studied through a model in which technology is seen as a structure of technological operations, and innovation characterized by a radical degree, measured by comparing previous technologies having the same purpose (Bonomi, & Marchisio, 2016). On the other side R&D, as being part of activity of start-ups with technological objectives, is seen as an organizing activity of knowledge and capitals generating a general knowledge, independently of its success, that constitutes a driving force in generating new innovative ideas (Bonomi, 2017a), process valid, not only for R&D projects, but also for start-ups activity. Furthermore, following the results of a simulation model of the R&D process (Bonomi, 2017b), we consider, in analogy of what it is observed in industrially financed R&D projects, that successful growth may be obtained only above some critical number of start-ups, and then of VC investments, characterizing a discontinuity in the relation between VC investments and economic growth.

After this introductory section, in a second section we discuss the nature and processes characterizing start-ups and in third section activities of VC especially concerning strategies in managing technical risks. In a fourth section, we describe the SVC financing cycle and its aspects concerning growth following different strategies in risk management. For these purposes, we have developed a simple mathematical simulation model of the cycle that it is reported in detail in the annex to this article. In a fifth section we summarize briefly the processes existing in R&D activity financed by industrial capitals following our model of the R&D process (Bonomi, 2017a) and its mathematical simulation (Bonomi, 2017b). In a sixth section, we discuss the comparison between the SVC system and industrially financed R&D project system in term of advantages and limits of both systems. Conclusion are reported in the seventh section.

2 START-UP

A start-up is a company of small dimension that begins its activity having, however, different characteristics compared with current small companies also beginning their activity. The difference of start-ups consists in their involvement in development of new technologies or application of new technologies in radical innovations of social or economic nature. Furthermore, start-ups are typically financed by VC and not by industrial or public capitals. Although start-ups are organized legally as a company, in fact their activity is more similar to a project defined as a not repetitive activity undertaken to achieve an objective within a time limit and budget or, in the case of start-ups, a capital. The objective of a start-up is the reaching of an exit that consists normally in the selling of the developed technology, typically to a great company, or collecting capitals, for example by be quoted in a stock exchange, in order to become an industrial company. With the exit of the start-up the VC obtains by selling the technology a ROI that it is used for a new reinvestment in developing other start-ups. The development of the activity of a start-up follows various phases that are explained in the following paragraphs.

2.1 Development phases of start-ups

The activity of a start-up begins with the generation of its innovative idea followed by various phases of development until its exit. This process, in the conditions of the best practice for the development of technological innovations, is similar to the development phases of an R&D project but it is accompanied by other than R&D activities in particular the development of a business model suitable for the type of developed technology and possibly commercial activities.

Generation of innovative idea

Technological start-ups are born by innovative ideas based on combination of preexisting technologies exploiting some new or never exploited phenomena discovered by science (Arthur 2009), but sometimes they may have the birth by the simple combination of preexisting technologies without any direct exploitation of scientific results (Bonomi & Marchisio, 2016). That was the case, for example, of invention of PC by Steve Wozniak in which exploitation of scientific results were only present in the technology of commercial components used for the invention. The generation of innovative ideas is favored by an innovative and entrepreneurial climate with free discussion and exchange of ideas and creativity as typically existing in the Silicon Valley. The common initial process in which the innovative idea begins its realization is called spin off. It consists in the leaving of researchers from university structures, public or private research laboratories and even industrial R&D laboratories deciding to develop an idea derived from their work in an autonomous manner. Typical is also the spin off from innovative firms as the case of Fairchild Semiconductors that, from 1959 to 1971, has generated directly or indirectly 35 start-ups, reaching presently the number of 92 that may be traced starting from this electronic industry of the Silicon Valley (Morris, 2014). However, spin off is not the only initial process of generation of a start-up, and sometime the origin is due to people that pursuit an innovative idea, even they had already during their education, that decide to leave their job that not necessarily is concerned by their innovative idea.

Prefeasibility phase

Once taken the decision to realize the innovative idea, it begins an initial step of prefeasibility looking for initial financing in order to verify the preliminary feasibility of the idea. This phase may include also limited experimental work and studies and it is financed typically by the founders of the start-up possibly also with small private or public funds. The objective of this preliminary phase is the finding of useful arguments to obtain more important financing for a feasibility phase of the start-up, typically obtained by VC or Business Angels, venture capitalists that act individually.

Feasibility phase

In this phase, the feasibility of the innovative idea is verified, however, this initial work does not bring to an accurate idea about possible performance and economical aspects of the innovation. This phase is, in technological start-ups, involved in experimental work possibly connected with scientific research.

Development phase

This step has the objective to determine the performances attainable by means of the innovation and to have a more accurate idea about its economy. As in the case of R&D projects this phase is the source of most of terminations of start-up projects and considered the Valley of Death that shall be overcame.

Industrialization phase

In this phase, the technology is developed to a stage making possible the exit process of the start-up consisting in selling the technology or by entering in a stock exchange market for collecting capitals necessary to become an industrial firm while VC has its return of investments made in developing start-ups.

The phases described above are similar to those of the R&D process (Bonomi, 2017a). The great difference between the development process of a start-up, in respect to the development of innovations through R&D projects industrially financed, is in the fact that start-ups integrate at the very beginning the R&D activity with other activities, particularly the search of a model of business suitable for the developed innovation, and even commercial activities near the end of their development.

2.2 Development of the model of business

The development of new business models represents an important aspect of technological and economical innovation in what it is called the regime of open innovation (Chesbrough, 2003). It is also an important activity for start-up development in order to match the developed technology with the best model of business for its exploitation. The term business model (Chesbrough & Rosenbloom, 2000) is widely used and the main functions of this activity are:

- Identification of a market segment in which technology is useful and for what purpose
- Articulate the value created for users and structure of the value chain i.e. network of firm's activity required to create and distribute products or services to customers
- Estimate cost structure and profit potential and formulate the competitive strategy by which the innovating technology will gain and hold advantage over rivals

In business models, the value thus derives from the structure of the situation, rather than from some inherent characteristic of the technology itself, and technical uncertainty is a function of market focus and it will vary with the dynamics of change in the marketplace (Chesbrough & Rosenbloom, 2000).

2.3 Commercial development

During the final phases of development of a start-up it is common the starting of commercial activities in terms of offer of products or services to the market. Such offer, however, has more the function of showing the validity of the technology in searching further important financing, than supplying financing to the start-up in form of commercial revenues. In fact, market knowledge is considered of main importance and market risks considered superior to technical risks in the start-up activity (Morgenthaler, 2000). Market acceptance risk and uncertainty, as in R&D project developments, may be reduced sensibly only in the final phases by testing directly the market (Scherer, 1999).

2.4 Structures and organizations promoting start-ups

Various types of structures or entities may promote the birth and activity of start-ups in a territory. Structures are primarily involved in favoring the various development phases while promoting entities are involved in supporting entrepreneurship, search of capitals, management, etc. and detailed as follows:

Promoting structures

Such structures are of various type following the various development phases. We have at the beginning co-working structures offering office emplacements in open spaces, meeting rooms, common equipment such as printers and photocopiers as well as meeting spaces with drinks vending machines or bar. A variant of co-working space is the open lab. It is a space with various equipment such as welding machines, tools, 3D printers, etc. useful to make prototypes. For start-ups in an advanced phase, there are incubators or accelerators that offer office spaces or even spaces for small productions or laboratory work. For more advanced start-ups, there are scientific or technological parks with availability of small industrial buildings.

Promoting organizations

Such organizations may be public or private entities, associations, etc. that have as primary or secondary objective promotion of start-ups with services such as coaching, mentoring, training and education, study tours, etc. Sometimes their help includes search of financing or even acting as source of seed capitals for the initial phases of start-ups.

3 VENTURE CAPITAL

For venture capital (VC) it is intended the typical form of financing the development of start-ups. Historically the first financing organization with the characteristics of modern VC was the American Research and Development (ARD) founded in 1946 by MIT President Karl Compton, Harvard Business School Professor Georges F. Doriot, and local business leaders (Lerner, 2000). Previous similar financing of new technologies is the case of Battelle Development Corporation (BDC), a not for profit subsidiary of the Battelle Memorial Institute, created in 1935 for financing internal R&D projects of Battelle Columbus Laboratories through their high risk period to the point where industry will take them over. Major result of BDC was in 1945 the agreement with Chester Carlson, inventor of photocopier, for financing the development of this invention sold later to Haloid, a small company becoming, after this development, the well-known Xerox Company (Bohem & Groner, 1972). The financing of technology developments of VC is radically different from that of industrial financing through R&D projects. The objective of industrial financing is the obtaining of a ROI by exploiting the new developed technology. VC objective is completely different and consists in obtaining an exit by selling the developed technology or the entire business of a start-up and reinvesting the obtained capitals from this return of investment in new technology developments through start-ups in a form of cyclic activity. Another form of VC is that of business angels, individuals that invest their own capital in start-ups. Business angels do not have normally great capitals such as big VC companies and tend to finance the initial phases of start-up development with seed capitals taking sometime more risky ventures. VC companies may be described in term of structure, financing strategies and selection methods in financing.

3.1 Structure of VC system

In territories in which the presence of start-ups is important, the VC tends to be differentiated by one side following the innovation field of start-ups, technological, socio-economic, etc. on the other side following the phase of development. In this case, there is a trading activity among VC companies that are involved in the various phases of financing the start-up development, adapting in a certain way the increase of capitalization with the decrease of risk and increase of potential ROI. In this way it is formed a market of start-ups with list of capitalization values that in the Silicon Valley are reported in local data banks that, of course, are associated to a high volatility.

3.2 Strategy of VC financing

The strategy of VC financing is conditioned by the reaching of a sufficiently high ROI in order to cover, not only the cost of development of the successful technology, but also capitals invested in abandoned start-ups and to have possibly margins for an increase of available capitals for further investments. Such constraint limits phases of start-up development in which the VC considers the investment. In particular VC never invests in scientific research and almost never in proving scientific principle. It rarely invests to develop an enabling technology but often invests in developing the use of a new technology or developing a new product. Very often, it invests in revising and improving a product, broadening a product line and applying a product to another application. Typically, VC considers in investing various elements of risk such as: size of the market, suitability of technology or product to the market needs. It considers also the organization building the development plan, and people that should implement the plan and also the possibility of financing, the rate of ROI that should be well above the minimum of VC goals and the realistic method of exit from the investment (Morgenthaler, 2000). In general, way portfolio strategies, largely used in financial activities, are of limited value in VC, not only in mitigating the downside risks inherent in science-based innovation projects, but also in enhancing the probability of exceptional rewards. VC portfolio must be closely scrutinized and cannot take in account a so high number of start-ups in order to have success in pure portfolio strategies, consequently there is the unwilling of the VC to invest in very young firms that only require small capital infusions but unwanted increase of the number of start-ups that must be scrutinized. The risk of technical failure is in achieving required performance specifications or in matching market needs. The alternative to portfolio strategy is to build a system of innovation designed primarily to maximize the probability of success for each project, limiting risk by selection of people in whom VC have confidence, both in the technical and the business dimensions of the enterprise (Branscombe & Auerswald, 2000). Actually, looking to characteristics of territories with high VC activity, such as the Silicon Valley, the fact that it is observed a large number of financed start-ups, accompanied by both high percentage of abandoned projects and very high ROI, it seems that, even if each VC company does not follow a portfolio strategy, the total set of VC companies acts in fact as following a portfolio strategy with an enough high number of start-ups to obtain statistically a certain number of very successful investments.

4 The Start-Up Venture Capital Cycle

The activity of the SVC system may be seen in form of a cycle as reported in Figure 1. The cycle starts with presentation of projects of start-ups to VC that selects start-ups that can be financed rejecting the others. Start-ups are financed and, following the developments, are abandoned or reach an exit. The technology or the entire business of start-ups is sold. The obtained ROI is in part retained by VC and the rest is reinvested in new start-up developments. This cycle is valid either for a single VC or group of VCs of a territory, and it is characterized by a certain number of average selection rates concerning: rate of accepted start-ups for financing, rate of abandoned start-ups, rate of return of investment in relation with the total invested capital, reinvestment in new start-ups with a part of return remaining to VC in order to cover its operational costs and rewards. This cycle presents a point of equilibrium defined by the value of rate between the obtained ROI and the invested capitals in successful start-ups. This rate shall be high enough to cover the total invested capitals in either successful or abandoned start-ups, increased by the operational costs and revenue of VC. If this rate is higher than the value of equilibrium, we will assist to an increase of reinvestment capabilities and, should be available an enough high number of start-up projects, to a continuous growth of new technologies and rewards. On the contrary, if this rate is lower than that of equilibrium, we will assist to a decrease of available reinvesting capitals, decrease of generation of new technologies and cycles characterized by a loss. It is interesting to know that about the average abandoning rates characterizing the cycles, there is a certain difference between American and European VC. The first characterized by higher abandoning rates, that in the Silicon Valley are estimated around 90%, but higher rates of ROI, the latter by a lower rate of abandoned start-up, estimated around 70-80%, but also lower rates of ROI. This difference might be attributed to difference in the adopted strategy in the selection of financed start-ups. In USA, as reported in the previous chapter, prevails a selection based on the potential generation of ROI and management quality of the start-up team. On the contrary, in Europe, it seems to prevail the estimation of the chance of success of the start-up while often the failure of a team in previous start-ups is considered negatively. Using a simple mathematical simulation of the start-up – VC cycle described previously, it is possible to study these two strategies in term of potential generation of reinvesting capitals and then of new financed start-ups. This mathematical simulation of the SVC cycle system has been carried out using an Excel® sheet (an example is given in Figure 3) and reported in detail in the annex of this article. The simulation considers a certain number of return rates making calculations following the different parameters characterizing the two strategies, naming Strategy A the typical strategy used in USA, and Strategy B the typical European strategy, described previously. For calculations, we consider the presentation of 100 start-up projects for financing in a first cycle. We assume in Strategy A 100% of accepted projects for financing, while in Strategy B projects are accepted in the range of 25 – 75%. We assume also that the relative average adimensional investment for any start-up is 10, independently if it is abandoned or if it reaches an exit. The rate of abandon of financed start-ups is assumed of 90% in the case of Strategy A and of 75% in the case of Strategy B. Finally, we assume that VC, to cover its operational costs and revenues, retains 20% of the ROI obtained by exits. As expected, the resulting value of the equilibrium rate is lower in Strategy B than in Strategy A in which the system should face a higher number of financed and abandoned start-ups. In fact, the calculated equilibrium rate is 5 for Strategy B and 12.5 for Strategy A. That means you should obtain in Strategy A a rate of ROI 2.5 times higher than in Strategy B in order to reach a financial equilibrium. The rate of equilibrium does not depend on the rate of acceptance of start-ups projects but only on the number of financed start-ups. In a second run, we have studied the effect of various rates of ROI up to four times the value of equilibrium for both strategies. Results are presented in Figure 4 showing that in Strategy A the increase of available capitals for reinvestment is higher than in Strategy B. In a last run, we have studied the increase of available reinvesting capitals with the accumulation of cycles for the two strategies considering a constant rate of ROI 1.5 higher than the value of equilibrium of respective strategies. The results, reported in Figure 5, show that in the case of Strategy A the increase of available reinvesting capital is much higher than in the case of Strategy B with the of cycles. Concluding the simulation model shows that Strategy A will be able, by accumulating cycles, to finance a much higher number of start-ups than Strategy B, and to have a greater probability to get exits with high ROI. We may observe that this difference is essentially consequent of the initial difference in number of financed start-ups, higher in Strategy A, and of the fact that we have attributed to this strategy the possibility to have exits with much higher ROI. In fact, the model calculations show that the ratio among the number of financed start-ups of Strategies A and B remains the same existing in the first cycle with the increase of cycles. Observing the results of the calculations, we may conclude that the key factor making more successful Strategy A is not linked to the activity of the cycle, that in fact presents linear dependences following the adopted parametric rates, but by the fact that Strategy A plays with a higher number of financed start-ups, increasing the statistical probability to obtain high returns, and its ability to select successful start-ups with high ROI. Following the model, we reach the conclusion that are the high rate of accepted start-up projects and the high availability of capitals enabling the financing of a high number of start-ups, joined with a coherent selection favoring high potential return of investments, at the base of success of Strategy A.

5 THE R&D PROCESS

A detailed description of the technological model of R&D used in this study may be found in a previous work (Bonomi, 2017a). In this model R&D is considered as an organizing activity of fluxes of knowledge and capitals generating new technologies in a cyclic process of financing R&D projects and reinvesting in new R&D projects using industrial capitals and possible public aids. The cycle starts with a selection of R&D project proposals for financing. The consequent R&D activity generates or not new technologies. As normally the R&D process leading to a new technology is composed by a sequence of project steps, at the end of each step the development is abandoned or continued by presenting a new project proposal for the advancement of the development until the last step in which technology is possibly fully developed. The final result of the R&D activity are new technologies, with corresponding invested capitals for their development. New technologies, as well imported technologies, enter in use financed by industrial capitals, with expected ROI, and availability of new capitals for R&D. On the other side the R&D activity generates new knowledge by either successful or abandoned projects. Such knowledge, combined with scientific and technical, as well as other types of knowledge, generates new innovative ideas, and then new R&D project proposals. The amount of generation in a territory of new R&D proposals by using available knowledge depends on efficiency of its innovative system. A schematic representation of the model of the R&D process is presented in Figure 2. Such model may be simulated mathematically, in a very simplified way, by studying the effect of starting R&D activity in a territory with a variable number of R&D projects, calculating the number of generated successful technologies with different levels of innovative territorial efficiency (Bonomi, 2017b). In fact, the mathematical model simulates R&D investments with the number of financed R&D projects, and economic growth with the number of obtained successful technologies (Bonomi, 2017b). The results of the mathematical simulation show that, depending on the initial number of R&D projects, and efficiency of the territory in generating innovative ideas, there is the formation of three regimes respectively of technological development, stagnation or decline. Furthermore, the results show that, because of the autocatalytic generation of knowledge by R&D activity, technology development (i.e. economic growth) is possible only above a critical number of R&D projects (i.e. R&D investments) resulting in a discontinuity in the relation between R&D investments and economic growth.

6 Discussion on the SVC and financed R&D projects systems

The SVC and industrially financed R&D projects systems present a certain number of similarities and some important differences. Comparing the schematic view of SVC and R&D processes reported respectively in Figures 1 and 2, we note that both present a financial cycle that, in particular for the R&D process, is represented by investments in developing new technologies, industrial capitals for their use, ROI and available capitals for investing in new R&D projects. In addition, in Figure 2 the R&D process presents also a knowledge cycle consisting in generation of innovative ideas, presentation of R&D project proposals, partly rejected and partly financed that constitute the projects of R&D activity. In fact, the R&D knowledge cycle is similar to that of start-up knowledge cycle that it is constituted also by generation of an innovative idea, its elaboration in form of a start-up project, presentation to VC for financing, selection of financed start-ups followed by start-up activities. As in the case of R&D, start-up activities generate knowledge by both successful or abandoned start-ups that, as GRDK of R&D activity (Bonomi, 2017a), constitutes a driving force for further start-up projects. The difference is in the fact that knowledge generated by start-up activities is enriched by other than technical knowledge as start-ups carry out not only R&D activities but also other ones such as business models and commercial developments. Considering now the financial cycle, there are actually radical differences comparing strategies between industrial capital and VC. In fact, industrial capital finances development of new technologies through R&D activities and looks for ROI based mainly on the use of the new technology. New investments in R&D by industrial capital does not depend by obtained ROI but by other factors depending on economic situation, firm strategies, existence of public aids, etc. On the contrary, VC obtains ROI by selling the new technology just after its development, and investing a great part of the returns in the development of new start-ups, retaining only a part for their operative costs and revenues, as described previously in the cycle model. In a start-up the main difference, in respect to a R&D project, is the presence of other than

R&D activities such as in particular the development of business models suitable for the developed technology, and commercial activity that have been described previously.

It is observed that often companies are biased making investments in technologies that do not fit with their established business models, while start-ups have the advantage of freedom in establishing the best business model suitable for the developed technology. In fact, it is a common opinion that established firms exhibit a systematic biased underinvestment or overinvestments in commercialization of novel emerging technologies while start-ups exhibit less of this bias (Chesbrough & Rosenbloom, 2000). In other words, the underinvestment or overinvestment bias is originated by considering an established model that may be not appropriate to the opportunities inherent in the new technology, while successful start-ups may better interpret the potential value of nascent technologies. In industrially financed R&D projects, questions about markets and strategies are taken in full consideration only in the advanced phases of the development and assumed mainly by the firm financing the project. By consequence only models of business compatible with the strategies of the firm are taken in consideration and, differently from the case of VC, a viable potentially successful new technology development may be abandoned if it cannot be included in the strategies of the firm. In fact, the frequently observed superior efficiency of start-ups in the R&D process, in respect to industrial R&D process, apparently reflects the superior quality of their technical personnel, greater cost consciousness, better understanding of the problem to be solved, and better communication (Branscombe et al. 2000). On the other side, the major limit of the SVC system is in the need of development of new technologies with very high ROI in order to sustain and develop the financing of the SVC cycle. In these conditions, the cycle shall be sustained by innovations with a high radical degree, but consequently at the same time having a high number of failures, as in fact it has been discussed previously. Another consequence of the SVC system may be observed in big companies that limit their R&D activity to their core business buying possibly more radical technologies by start-ups (Branscombe et al. 2000). Consequently, the main advantage of industrial financed R&D projects is in the possibility to develop technological innovations with relatively lower ROI, eventually with a lower radical degree and lower risk of failure. It remains open the case of financing development of small business projects or technologies of public interest, for example in the environmental field, that are neither of interest of VC and nor often also of industrial capitals. A problem of this type might become important for example in SMEs of industrial districts for fostering the radical degree of their innovations and for implementing new technologies as in the case of Industry 4.0. The possibility of use of public financing of start-ups in compensating an insufficient availability of VC might be considered negatively because of lack of experience of public officials in sustaining a successful SVC cycle. However, public aid may be useful in the preliminary phases of development of start-ups looking for VC financing. The question of public financing of start-ups has been discussed in a workshop about managing technical risks (Lerner, 2000) concluding in a series of recommendations in carrying out a public VC program such as: building relationships and understanding of VC industry, considering the narrow technological focus and uneven levels of VC investments, appreciating the need of flexibility in the VC investment process, carefully analyzing the track record of entrepreneurs and examine the track record of the firms receiving public venture awards. In fact, the problem remains in how to obtain enough ROI to sustain a public financed cycle for start-ups. Public financing may avoid retained revenues and operational costs, taken in charge by general expenditures of administration, and that may reduce the value of equilibrium rate of the cycle and necessary ROI, but that could not be necessarily enough for a financial equilibrium of the cycle. The question is then how much public funds should be continuously fed to the SVC cycle in maintaining benefic general effects through start-up developments.

7 CONCLUSIONS

This study has discussed the main difference between the SVC and industrially financed R&D projects. This difference consists mainly in the radical position of VC investing in development of new technologies but looking for a ROI based on selling the technology, and not on exploitation of its use. On the other side start-up activities differ from R&D projects because of inclusion of other activities such as development of models of business, optimized in respect to the developed technology, and commercial activities with the aim to show the validity of the developed technology. The SVC system appears more favorable to the development of radical innovations, but needs for that high ROI. On the other side the industrially financed R&D projects system remains valid for the development of innovations with lower ROI and with a lower radical degree but also often lower competitive potential. It remains open the problem to support public programs operating the SVC cycle for small business radical innovations, or other technologies of public interest that are neither of interest for VC, nor for industrial capitals.

The great success observed for the SVC system from one side depends on ability of VC to select start-ups with high ROI in spite of a high risk of failure, and managing efficiently the uncertainness existing in development of radical innovations. Such abilities appear more linked to a know-how acquired with experience than to already known strategies, and it is probable that large part of this know-how derives from past experience on failure of start-ups. From the other side this great success depends also on the availability of an innovative and entrepreneurial climate with free discussion and exchange of ideas and creativity generating a great number of start-ups projects. Of great importance is also the existence of technological sectors with a very high potential for innovations. Although that has been demonstrated only for the ICT of the Silicon Valley, other potential technological sectors may present the same characteristics. These sectors might be for example nanotechnologies or biotechnologies, these last however penalized having time to market for innovation quite long because of necessity to follow protocols established in the case of products concerning human health. Another sector in which the SVC cycle might be of interest is the integration of ICT with operational manufacturing technologies as in Industry 4.0, as well as in numerous applications of artificial intelligence. Important is also the finding of conditions in which it would be possible to operate the cycle with relatively low returns of investment but boosting the radical degree of innovations. Finally, we should observe that the radical strategy of VC in financing deeply technological innovations has shown, through its success, the key role of technology in generation of economic growth already observed in the study of the R&D process (Bonomi, 2017).

8 References

Arthur, B. (200). *The Nature of Technology*. New York: Free Press.

Boehm, G., & Groner, A. (1972). *Science in the Service of Mankind*. Lexington, Mass: Lexington Books.

Bonomi, A., & Marchisio, M. (2016). *Technology Modelling and Technology Innovation: how a technology model may be useful in studying the innovation process* (CNR-IRCrES Working Paper 6/2016). Moncalieri, TO: Consiglio Nazionale delle Ricerche, Istituto di Ricerca sulla Crescita Economica Sostenibile. http://www.ircres.cnr.it/index.php/it/produzione-scientifica/pubblicazioni?id=118

Bonomi, A. (2017a). *A Technological Model of R&D Process, and its implications with scientific research and socio-economic activities* (CNR-IRCrES Working Paper 2/2017). Moncalieri, TO: Consiglio Nazionale delle Ricerche, Istituto di Ricerca sulla Crescita Economica Sostenibile. http://dx.doi.org/10.23760/2421-7158.2017.002

Bonomi, A. (2017b). *A Mathematical Toy Model of the R&D Process: how this model may be useful in studying territorial development* (CNR-IRCrES Working Paper 6/2017). Moncalieri, TO: Consiglio Nazionale delle Ricerche, Istituto di Ricerca sulla Crescita Economica Sostenibile. http://dx.doi.org/10.23760/2421-7158.2017.006.

Branscombe, L., & Auerswald, P. (2000). *Taking Technical Risks*. Cambridge MA: MIT Press.

Branscombe, L., Morse, K., Roberts, M., & Boville, D. (2000). *Managing Technical Risk: Understanding Private Sector Decision Making on Early Stage Technology-based Projects* (NIST GCR 00-787) US Department of Commerce.

Chesbrough, H. (2003). *Open Innovation: The New Imperative for Creating and Profiting from Technology*. Harvard Business School Press.

Chesbrough, H.W., & Rosenbloom R. (2000) The Dual-Edged Role of the Business Model in Leveraging Corporate Technology Investments. In Branscombe, L., Morse, K., Roberts, M., & Boville, D. (2000). *Managing Technical Risk: Understanding Private Sector Decision Making on Early Stage Technology-based Projects* (NIST GCR 00-787). US Department of Commerce.

Haour, G. (2004). *Resolving the Innovation Paradox: Enhancing Growth in Technology Company*. New York, N. Y.: Palgrave Macmillan.

Lerner, J. (2000). When Bureaucrats Meet Entrepreneurs: The Design of Effective Public Venture Capital Programs. In Branscombe, L., Morse, K., Roberts, M., & Boville, D. (2000). *Managing Technical Risk: Understanding Private Sector Decision Making on Early Stage Technology-based Projects* (NIST GCR 00-787) US Department of Commerce.

Morgenthaler, D. (2000). Assessing Technical Risk. In Branscombe, L., Morse, K., Roberts, M., & Boville, D. (2000). *Managing Technical Risk: Understanding Private Sector Decision Making on Early Stage Technology-based Projects* (NIST GCR 00-787) US Department of Commerce.

Morris, R. (2014). The First Trillion-Dollar Startup. *Endeavour Insight Monthly Newsletter*, Jul. 26, 2014.

Scherer, F.M. (1999). *New Perspectives on Economic Growth and Technological Innovation.* Washington, DC: Brookings Institution Press.

9 ANNEX: MATHEMATICAL SIMULATION MODEL OF THE START-UP VENTURE CAPITAL SYSTEM

The activity of the SVC system has a cyclic nature that has been presented in Figure 1. The cycle starts with a certain number of start-up projects that are submitted to venture capital for financing. Part of these proposals are accepted, the remaining rejected. Accepted start-ups are financed and during the development part of start-ups are abandoned, the remaining reach an exit that produces a ROI to VC. Part of this return remains as margin to VC and rest of capital is reinvested for financing new start-ups. The equilibrium point of this system is reached when available capital for investing in new start-ups is equal to the capital invested at the beginning of the cycle. That means that the ROI of exits shall be higher than this initial capital to compensate the return to the VC covering its operative cost and possible revenue. In the activity of the SVC cycle we may distinguish two important strategies concerning the selection of financed start-ups as follows:

Strategy A. In this case in the selection it is considered primarily the potential ROI of the project and the capacity and experience of the team, while the feasibility of the project is taken in account but considered too much uncertain to be the main criteria of choice, preferring the financing of a high number of start-ups in order to increase the probability of exits reaching a great ROI.

Strategy B. In this case the feasibility of the project is of main importance in the choice, and suitable methods for its determination are taken in consideration in order to reduce losses dues to abandoned start-ups. Experience of the team has not the same importance as in Strategy A, and in certain case the failure of a team in previous start-ups is considered negatively instead of an occasion to cumulate experience in start-up management.

These two strategies may be studied in the SVC system by developing a mathematical simulation based on the cycle reported in Figure 1. In the simulation it is considered the case of a territory in which are operating a certain number of VC companies financing start-ups and in which, at the beginning of a cycle, are presented a certain number of start-up project proposals. These proposals may be selected following Strategy A or B. The number of chosen start-up for financing will be higher in Strategy A than in Strategy B. On the other side the number of abandoned start-ups will be lower in Strategy B than in Strategy A, as it may be deduced by the description of the two strategies. These two strategies have a point of equilibrium described previously, and it is expected that point of equilibrium in Strategy A will correspond to higher ROI than in Strategy B. Such situations of equilibrium may be considered in the simulation model calculating the value of the average ROI of start-ups exit satisfying this condition. Starting from this point of equilibrium it also possible to carry out parametric studies for the two strategies calculating the effects of an increase of ROI in respect to the value of equilibrium and the increase of capital available for reinvestment with the increase of number of cycles.

Calculation of the equilibrium point following the mathematical simulation model

The calculation has been made using an Excel® sheet, and an example is given in Figure 3. We consider a first cycle with an initial number P of start-up projects proposals, assumed equal to 100. In this case the number of accepted proposals S will be given by:

$$S = sP \quad (1)$$

in which s represents the rate of accepted projects. In the Strategy A we assume that there is always a full financing of all proposed projects and s will be equal to 1. In Strategy B the number of accepted proposals will be lower and s may assume various values considered in our calculations varying from 0.25 to 0.75. We may indicate as f the average financing of each start-up, and assume that it has an adimensional relative numerical value of 10. Actually, there might be a difference in average capitals invested in abandoned or successful start-ups that could be higher in the case of successful ones. However, we consider that this possible difference would not affect greatly the calculated results and discussion on their value. Consequently, the total financing F of VC will be:

$$F = fS \quad (2)$$

Considering now the rate of abandoning of the S financed start-ups a, the number A of abandoned start-ups will be:

$$A = aS \quad (3)$$

The rate a will be different following the different strategies and we assume a value of 0.9 for Strategy A and of 0.75 for Strategy B as discussed previously un the case of Silicon Valley and Europe. Then the number E of start-ups having a positive exit will be:

$$E = (1-a)S \quad (4)$$

Considering now an average value r of the ROI of each start-up having a positive exit, the total return of investment R is given by:

$$R = rE \quad (5)$$

In condition of equilibrium R should cover the entire capital F invested plus operational cost and revenue of VC. Indicating with v the fraction of return of investment R that it is retained by VC, the available capital C for reinvestment in start-ups development will be given by:

$$C = R(1-v) \quad (6)$$

and the conditions of equilibrium of the cycle is obtained when:

$$C = F \quad (7)$$

The value of R at the point of equilibrium of the two strategies may be obtained by iterative calculations based on varying the value of the average return of investment r of successful start-ups. The R value of equilibrium will be of course different in the case of Strategy A or B, and also in the case of different chosen values of acceptance *a*. Making calculations we have considered the following starting parameters for the two strategies:

Strategy A
Rate of financing *s* = 1
Rate of abandoning *a* = 0.9

Strategy B
Rate of financing *s* = variable from 0.25 to 0.75
Rate of abandoning *a* = 0.75

The results are:

Strategy A
Average r per exit at the equilibrium: 125
Ratio *r/f* at the equilibrium: 12.5

Strategy B
Average r per exit at the equilibrium: 50 (independently of the value of *s*)
Ratio *r/f* at the equilibrium: 5

It should be noted that, as expected, the *r* value necessary for equilibrium in Strategy A is much higher than in the case of Strategy B (12.5 against 5) corresponding to a ratio between the two values of 2.5. The independence of value of s from the value a of acceptance observed for Strategy B is a consequence of the proportional decrease of need of financing capital F with the number of S of financed start-ups in the established conditions of equilibrium. In fact, a parametric study taking constant the selection rate (*s* equal to 0.5) of Strategy A but varying the abandon rate *a* from values of 0.9 to 0.6, the results of value of *r* in the conditions of equilibrium vary from 125 to 31.5, and consequently the ratio *r/f* from 12.5 to 3.2.

Parametric calculations

Following the cycle of the model the number of start-ups S' that can be financed in a second cycle, assuming the same average financing value *f* of the first cycle, will be given by:

$$S' = C/f \quad (7)$$

The cycle will be in condition of development if S' > S and in condition of loss if S' < S. It is then possible to do a parametric study calculating the variation of number of start-ups that may be financed following an increase of *r*, and then of ratio *r/f*, in respect to the value of equilibrium with rates changing from one to four times the value of equilibrium, and considering the following initial conditions for the two strategies:

Strategy A: *s* = 1 and *a* = 0.9
Strategy B: *s* = 0.5 and *a* = 0.75

Calculations show that the number S' of new financed start-ups increases proportionally with the increase of the adopted ratio *r/f*, in respect to the initial value of equilibrium of such ratio. As indicated in Figure 4 the rate of increment of S' s higher in the case of Strategy A than in Strategy B showing more financing potential of start-ups for Strategy A.

In a last run of the parametric study we have studied the cumulation of number of financed start-ups with the number of cycles for the two strategies considering an initial number of 100 start-ups projects and a ratio *r/f* of 1.5 valid respectively for both strategies. As reported in Figure 5 the results show an increase from 150 start-ups financeable after the first cycle to 2570 after the eighth cycle for Strategy A. In the case of Strategy B, the increase is from 76 after the first cycle to 1295 after the eighth cycle showing another time the much higher financing potential of Strategy A. Concluding the calculations made on the cycle show that the development of the SVC cycle depends on the exit ROI and on number of exits and not by selection rate of start-up projects but rather by the higher ROI resulting by a successful application of Strategy A.

10 FIGURES

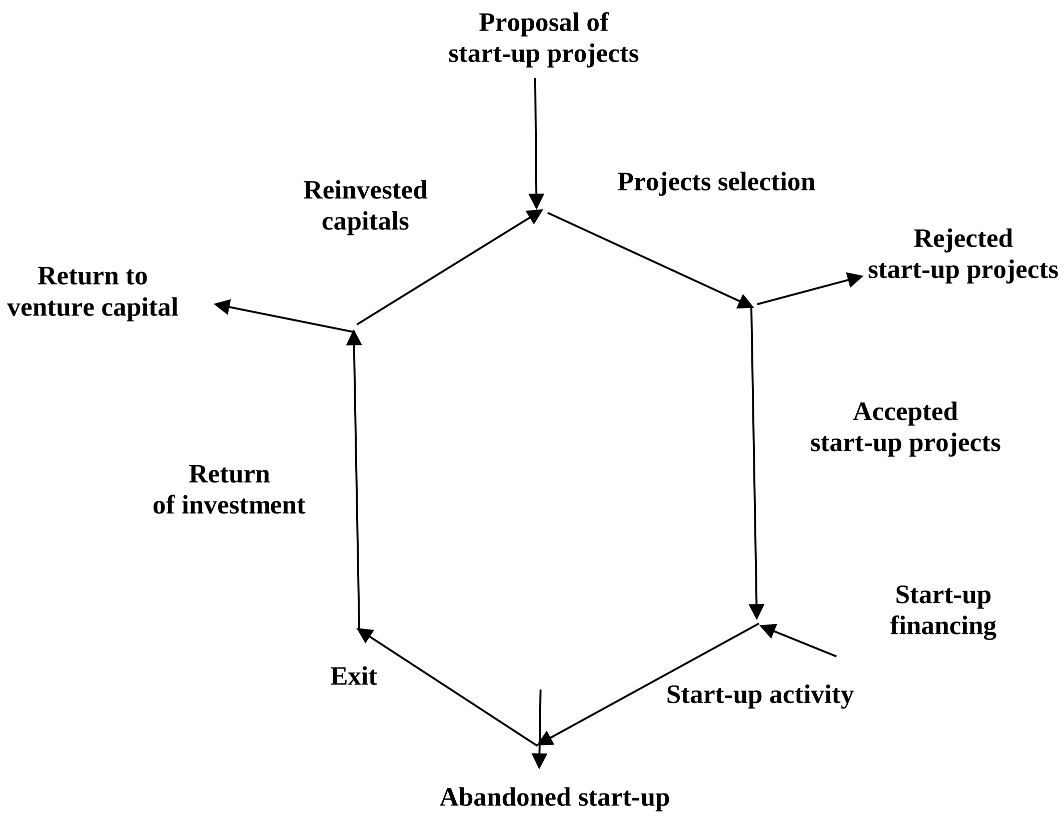

Figure 1. Start-up Venture Capital Cycle.

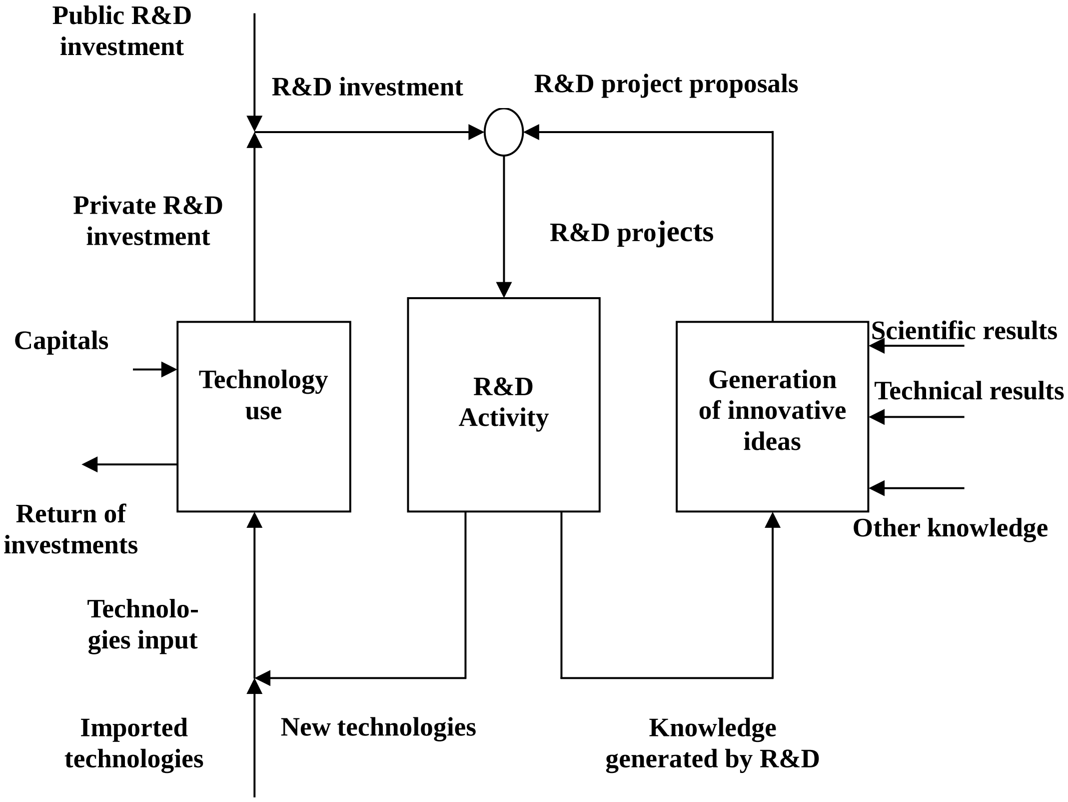

Figure 2. Schematic view of the R&D process cycle.

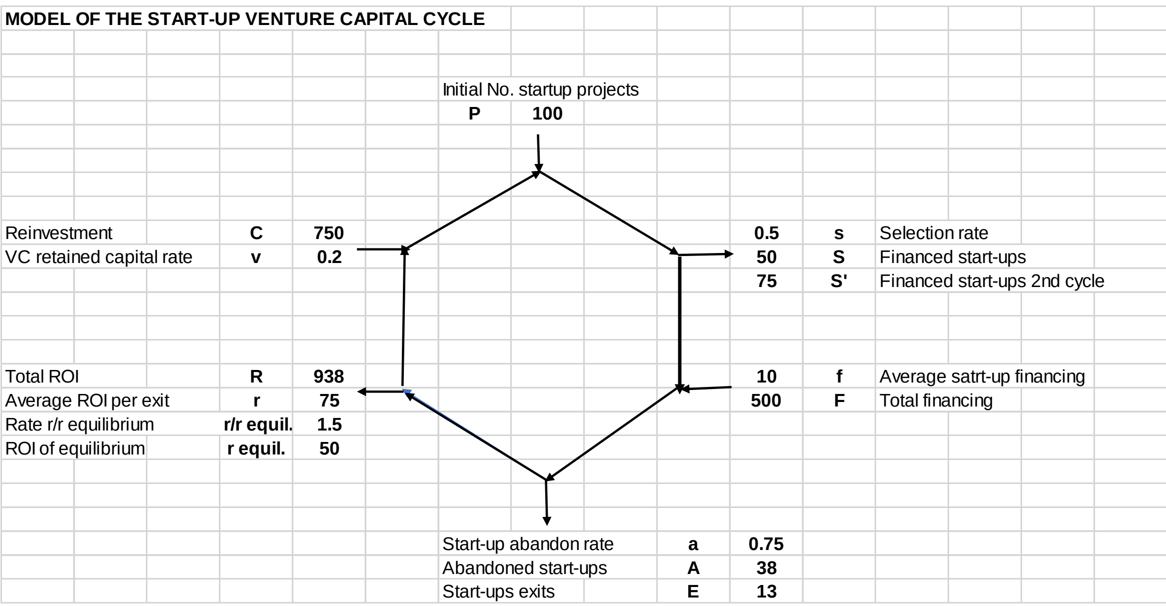

Figure 3. View of the Start-up VC cycle represented in an Excel® sheet.

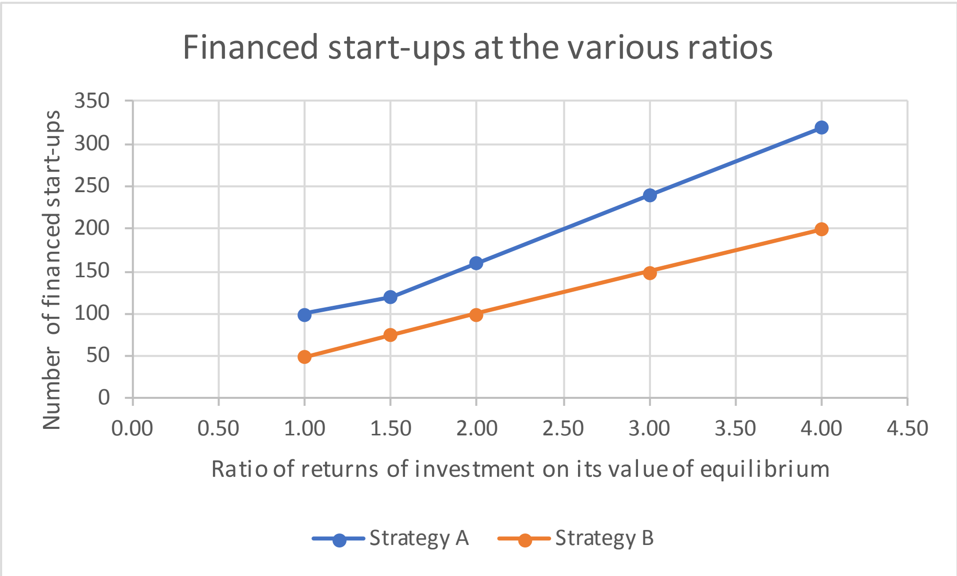

Figure 4. No. of financed start-ups as a function of ratio of ROI on its value of equilibrium.

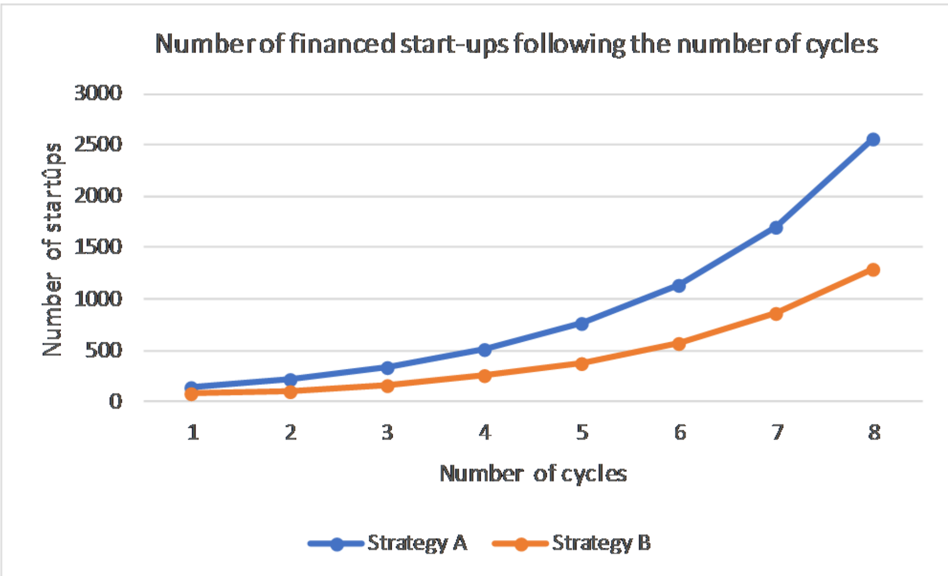

Figure 5. Number of financed start-ups as a function on number of cycles.